is particularly acute if the performance review is used to measure achieved productivity growth and to adjust prices or the next period productivity offset to account for productivity successes or failures.[26] The risk of not updating the offset is that prices may not move with costs over time. Given the risks and the relatively short duration of the price cap period--short relative to the volatility of TFP measures--updating the productivity offset in performance reviews or at the annual price cap filing is inferior to maintaining a stable offset as a matter of principle.

2. Productivity Conclusions

This assessment of alternatives to the current productivity offset for the LEC price cap plan is hampered by lack of data because the plan has been in existence for only three years. Nonetheless, the long-run historical picture from Figure 4 shows that the industry as a whole could not expect to achieve the productivity growth implicit in the Commissions 3.3 percent productivity offset. The inflation and productivity offset components of the price cap formula are working within the bounds contemplated by the Commission when the plan was begun, and the danger of reversing the improvements in the incentives of regulated LECs far outweighs any benefits from attempting to fine-tune these components of the plan.

[26] If prices in the next period depended on productivity growth achieved in the current period, the firm would receive the perverse signals that failures in the current period would be rewarded with higher prices in the next period and successes in the current period would be punished by lower prices in the next period.

IV. ADJUSTMENT FOR INTEREST RATE CHANGES

The Commission has requested comment on whether (i) it may be appropriate to adopt a mechanism for adjusting the price cap to reflect changes in interest rates or (ii) if a one-time change in the price cap index may be required. A rate adjustment to account for changes in interest rates is not necessary and would essentially double-count the mechanism by which changes in input prices are accounted for under the plan. There is no basis for a one-time change in the price cap index.

As shown above in equation (3), the price cap plan includes historical differences--if any--in the rate of growth of input prices between the telecommunications industry and the U.S. as a whole as part of the productivity offset X. Thus if factor prices fall, the price cap-regulated firm will benefit to the extent that its costs fall further than those of a typical firm in the U.S. economy. Conversely, when factor prices rise, the regulated firm will benefit if its costs rise less than those of other firms in the economy.

Thus, if one factor price (e.g., the price of capital services) changes because of changes in interest rates, much of the impact on the regulated firm would be captured in the GNP-PI, because all firms in the economy face the same economic conditions that would have caused a secular increase or decrease in capital costs. The regulated firm would benefit only to the extent that it could manage its business so that the effect of the factor price change on it were more favorable than on the average firm in the U.S. economy. In the current FCC price cap plan for LECs and for AT&T, the regulated firm is given that incentive to manage its input prices as best it can because the input price growth differential in equation (3) is included as part of the productivity offset X and is not updated every year (as inflation is updated) in the annual filing.

Note that if it were determined important to adjust the price cap index for changes in input prices, it would still be incorrect to simply reset prices--or the price cap index--to flow-through a lower cost of capital. First, it would be wrong to adjust the price cap index for changes in one factor price and not all factor prices. Equations (1) and (3) show that all input price changes are present in the annual adjustment formula, and it would impart a bias in factor proportions if adjustments were made to reflect changes in one factor price but not another.[27] Hence if adjustments were made to flow-through changes in the cost of capital, the only proper way to do that would be through changes in the rate of growth of all factors of production.

Second, it would be wrong to adjust the price cap index by the change in costs associated with the changes in capital (or all factor) prices. As shown in equations (3) and (4), the annual price adjustment formula changes by the difference between the change in the telecommunications industry's factor price growth and that of the U.S. as a whole. To lower the price cap index by the change in costs implied by a lower interest rate would effectively double-count a portion of the effect of the cost change. The (assumed) reduction in interest rates reduces costs for other firms in the economy which, ultimately, are flowed through to consumers in the form of lower prices. Lower prices imply that

[27]Recall that for a cost-minimizing firm, demands for factors of production (capital, labor and raw materials) depend on the relative prices of those factors. If the price cap formula distorted the ratio of the price of capital and labor effectively faced by the firm--by passing through changes in capital prices but not labor prices in the price cap annual adjustment formula--it would subsequently distort the choices of productive technology, interfere with cost minimization, and impart a bias in factor proportions not unlike the Averch-Johnson bias of traditional RoR regulation.

the growth in the measure of national inflation (GNP-PI) is lower that it otherwise would be and thus that the regulated firm's price cap index would be lower than it would have been, absent the reduction in interest rates.[28]

This is not, however, the plan that the FCC adopted for AT&T or for the LECs, and there are good reasons not to adopt such a plan. First, as shown above in Figure 1, there are no long run differences in the rate of growth of input prices between the telecommunications industry and the U.S. as a whole. Second, measured input price growth differences are extremely volatile which would impart more variability to the price cap index. Third, measurement of input price growth is difficult and imprecise, and no competent disinterested party currently calculates such indices. Finally, adjusting output prices every year to account for the differential effect on the LECs of changes in input prices eliminates their incentives to control--to whatever extent is possible--the prices of the inputs they purchase.

Having adopted an incentive regulation plan, the temptation to fine-tune the annual price adjustment formula to account for specific factors that might change short-run costs should generally be resisted; otherwise, price cap regulation would degenerate into traditional RoR regulation, and none of the incentive improvements intended by the adoption of price cap regulation would be realized. Under no circumstances would it be appropriate--or, indeed, arithmetically correct--to simply reset existing prices or the existing

[28]To adjust the price cap index--or the level of prices--for changes in interest rates amounts to treating factor price changes as exogenous cost changes. In this context, it is clear that since factor price changes affect all firms in the economy-- albeit differentially--only the difference between the effect of the cost change on the regulated firm and on the average firm in the economy would be eligible for exogenous cost treatment.

price cap index to reflect a change in rate of return. Such a suggestion is just a vestige of rate of return regulation and has no place in a price regulation plan.

V. CONCLUSIONS

We have examined evidence since 1990 regarding the LECs' experience with key economic parameters of the Price Cap Plan. With respect to the measure of inflation, we found a slight theoretical preference for use of the GDP-PI but no real difference in the behavior of the indices. Past historical trends strongly suggest that a 3.3 percent productivity differential would be difficult to achieve. If any change were warranted in the productivity offset, the evidence shows that the change would be downward. Finally, a rate adjustment to account for changes in interest rates is not necessary, would be inconsistent with the proper workings of the price cap plan adopted by the FCC, and would have to reflect differences in growth rates of all LEC input prices measured with respect to the growth rates of input prices in the economy.

VI. APPENDIX I

The annual price cap adjustment formula is designed so that if the firm achieves the industry productivity goal, the allowed growth in its price cap will just equal the realized growth in industry input prices. Following, we demonstrate that TFP is the appropriate foundation for a productivity offset in the price cap plan. Assume the price cap plan begins with appropriate prices so that the value of total inputs (including a normal return on capital) equals the value of total output. We can write this relationship as

$$\sum_{i=1}^{N} p_i \, Q_i = \sum_{j=1}^{M} w_j \, R_j \ ,$$

where the firm has N outputs (Q_i, i=1,...,N) and M inputs (R_j, j=1,...,M) and where p_i and w_j denote output and input prices respectively. We want to calculate a productivity offset so that--if the firm meets the industry productivity offset--this relationship holds identically at all points in time.

Expressing this identity in growth terms (differentiating this identity with respect to time) yields

$$\sum_{i=1}^{N} \dot{p}_i \, Q_i + \sum_{i=1}^{N} p_i \, \dot{Q}_i = \sum_{j=1}^{M} \dot{w}_j \, R_j + \sum_{j=1}^{M} w_j \, \dot{R}_j ,$$

where a dot (a derivative with respect to time) indicates growth over time. Dividing both sides of the equation by the value of output ($REV = \sum_i p_i \, Q_i$ or $C = \sum_j w_j \, R_j$), we obtain

$$\sum \dot{p}_i \left(\frac{Q_i}{REV} \right) + \sum \dot{Q}_i \left(\frac{p_i}{REV} \right) = \sum \dot{w}_j \left(\frac{R_j}{C} \right) + \sum \dot{R}_j \left(\frac{w_j}{C} \right),$$

where REV and C denote revenue and cost. If rev_i denotes the revenue share of output i and c_j denotes the cost share of input j, then

(5) $$\sum_i rev_i \, dp_i = \sum_j c_j \, dw_j - [\sum_i rev_i \, dQ_i - \sum_j c_j \, dR_j],$$

where d denotes a percentage growth rate: $dp_i = \dot{p}_i / p_i$. The first term in equation (5) is the revenue-weighted average of the rates of growth of output prices, and the second is the cost-weighted average of the rates of growth of input prices. The term in brackets is the difference between weighted averages of the rates of growth of outputs and inputs. It thus is a measure of the change in industry TFP. Rewriting the equation for clarity, we see that

$$dp = dw - dTFP.$$

In words, the theory underlying the LEC annual price cap adjustment formula implies that the rate of growth of a revenue-weighted output price index is equal to the rate of growth of an expenditure-weighted input price index plus the change in total factor productivity, not labor productivity or any other productivity measure. This equation demonstrates that total factor productivity is the appropriate foundation for a productivity offset in the price cap plan: if the plan begins with revenues which match costs--and if the firm attains a productivity goal measured in terms of industry total factor productivity--then the firm's revenues will continue to move with industry costs.

Productivity of the Local Operating Telephone Companies Subject to Price Cap Regulation

Laurits R. Christensen, Philip E. Schoech,

and Mark E. Meitzen

Christensen Associates

May 4, 1994

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EXECUTIVE SUMMARY

Productivity of the Local Operating Telephone Companies Subject to Price Cap Regulation

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This report summarizes the results of the Total Factor Productivity study of the price cap Local Exchange Carriers (LECs), which was commissioned to Christensen Associates by the United States Telephone Association (USTA). Total Factor Productivity (TFP) is the ratio of total output to total input, where total output includes all services provided by the Local Exchange Carriers and total input includes the capital, labor, and materials used to provide those services.[1] The companies included in the study are Ameritech, Bell Atlantic, BellSouth, GTE, NYNEX, Pacific Telesis, Southern New England Telephone, Southwestern Bell, and U S West. The study covers the period 1984-1992. When the study was performed, this was the longest time period for which post-divestiture data were available for the LECs. In addition, this report presents a theoretical framework for analyzing sources of TFP growth, summarizes empirical studies of TFP growth in the telecommunications industry, and provides an analysis of TFP implications for LEC services subject to emerging competition.

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[1]Total output consists of all services included in total operating revenue, as currently defined in the Form M.

EXECUTIVE SUMMARY

Chapter 1 presents the results of the LEC TFP study. The results of the study are that over the 1984-1992 period, total output for the price cap LECs grew at a 3.5 percent average annual rate and total input grew at a 0.9 percent average annual rate, resulting in average annual TFP growth of 2.6 percent. The productivity offset in the price cap formula is related to the differential in productivity growth between the LECs and the U.S. economy. Given that economy-wide TFP growth has averaged approximately 0.9 percent annually since 1984,[2] LEC post-divestiture TFP growth has exceeded economy-wide TFP growth, with a TFP growth differential of 1.7 percent.

The methodology employed in this study was initially developed for our 1981 study of the Bell System,[3] and subsequently has been applied in studies submitted to and accepted by the public utility commissions in North Dakota, Georgia, Illinois, Ohio, and Indiana. It is based on research conducted by Laurits Christensen and Dale Jorgenson into the measurement of TFP growth in the U.S. economy.[4] The data

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[2]The economy-wide TFP figure is based on the U.S. Bureau of Labor Statistics' measure of "multifactor" productivity for the private business sector of the U.S. economy. Bureau of Labor Statistics multifactor productivity measures are reported in the BLS publication, Monthly Labor Review.

[3]Laurits R. Christensen, Dianne C. Christensen, and Philip E. Schoech, "Total Factor Productivity in the Bell System, 1947-1979." Christensen Associates, September 1981.

[4]L.R. Christensen and D.W. Jorgenson, "The Measurement of U.S. Real Capital Input, 1929-1967," Review of Income and Wealth, Series 15, December 1969, pp. 293-320; L.R. Christensen and D.W. Jorgenson, "U.S. Real Product and Real Factor Input, 1929-1967," Review of Income and Wealth, Series 16, March 1970, pp. 19-50; and L.R. Christensen and D.W. Jorgenson, "U.S. Income, Savings and Wealth, 1929-1969," Review of Income and Wealth, Series 19, December 1973, pp. 329-362.

requirements of the methodology are met with company records and, in fact, most of the required data are filed annually with the Federal Communications Commission.

To measure total output, seven different types of services are distinguished: local service, interstate end user access, interstate switched access, interstate special access, intrastate access, long distance service, and miscellaneous services. Price changes are factored out of each category's revenues to obtain quantity indexes. The quantity indexes for the revenue categories are aggregated into an overall output quantity index.

The weights used in the computation of the output index are the revenue shares of the services contained in the index. For purposes of determining the productivity offset in a price cap formula, this is the proper specification for the output index. By employing the revenue weighted output index, prices paid by LEC customers can be linked to changes in input price inflation and changes in TFP.[5] Proper specification of the output index is important because changes in output growth are directly related to changes in TFP growth.[6]

Total input is comprised of capital (plant and equipment), labor, and materials (purchased materials, rents, and services). To construct a quantity index of total input, we first construct separate quantity indexes for capital, labor, and materials.

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[5]This relationship is formally presented in Appendix 1.

[6]Chapter 2 explores in detail the relationship between output growth and TFP growth.

The capital, labor, and materials quantity indexes are then aggregated into an overall input quantity index with cost shares serving as the weights for the input categories.

To measure capital input, six asset classes are distinguished: buildings, general support equipment, central office equipment (including operator systems), transmission equipment, information origination/termination equipment, and cable and wire. Quantity indexes and annualized costs are calculated for each of the asset classes; then an overall quantity index of total capital input is computed from the asset classes, with their cost shares used as weights.

Labor input is the time spent by LEC employees in providing services to LEC customers. It does not include the time spent installing plant and equipment, since this time is included in the capital input measure. Two groups of employees are distinguished in the study: management and non-management. The quantity index of labor input is an index of management and non-management hours worked, with management and non-management labor cost shares used as weights.

The cost of materials is equal to total operating expense less depreciation and payments to labor. Since this category is comprised of a diverse set of inputs, the U.S. Gross Domestic Product Price Index (GDPPI) is used to represent the price of materials. The quantity index of materials is obtained by dividing materials cost by its price.

Chapter 2 provides the theoretical framework for analyzing sources of TFP growth and reviews empirical studies of TFP growth in the telephone industry. A primary source of TFP growth in the telephone industry is output growth. Furthermore, services that have relatively high levels of contribution to joint and common costs (i.e., low marginal costs relative to price) have relatively greater contributions to TFP growth. Two service groups with relatively high contribution margins are also areas that will be facing increased competition in the future--intra-LATA toll and switched access. As competition increases in these services, LECs are faced with the prospect that future output growth in these areas will be less than historical growth, leading to downward pressure on TFP growth.

Chapter 1
Total Factor Productivity Study

In this chapter, we describe the methods used to calculate total output (Section 1.1), and total input (Section 1.2). In Section 1.3 we present the annual figures for total output, total input, and Total Factor Productivity. Most of the data used in the computations come either from the Form M annual reports filed with the FCC or were supplied to us directly by the LECs. We have reviewed all data to ensure that they are reasonable and appropriate.

1.1 Total Output--Methods

The Local Exchange Carriers provide a variety of telecommunications services; consequently LEC output cannot be adequately measured using simple physical indicators such as access lines, number of calls, or minutes of use. To properly measure output, different types of LEC services must be distinguished, and for each service category, price and quantity indexes must be developed that accurately represent the complexity and diversity of telephone operations. We measure seven major categories of services: local service, interstate end user access, interstate switched access, interstate special access, intrastate access, long distance service, and miscellaneous services. For each of these service categories, a price index is constructed to represent price changes that occurred during the study period. The price indexes are used to factor price changes out of each service category's revenues, yielding an output quantity index for each service category.

Output by Category

The company Form M annual reports show booked revenue for each of the service categories listed above. When using these data, it is important to make adjustments for changes in accounting definitions. In particular, the mandated accounting revisions in 1988 must be addressed.[1] The primary difference between reported operating revenue through 1987 and reported operating revenue beginning in 1988 is revenue from certain nonregulated services. Beginning in 1988, all revenue from nonregulated services that had joint and common costs with regulated services were reported in operating revenue. Before 1988 this was not the case. The LECs provided Christensen Associates with adjustments to the Form M booked revenues for the 1984-1987 period in order to put revenues from the two periods (1984-1987 and 1988-1992) on a consistent accounting basis. These adjustments apply to the miscellaneous services category.

Price indexes for local service, intrastate access, and long distance service are constructed from the price change information reported by the LECs in the Form M.[2] In the Form M, the LECs report the impact of rate changes in terms of changes in revenue. The methodology we use converts the dollar change in revenue to a percentage change in the overall rate level. These percentage changes in rate levels

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[1]This is the Uniform System of Accounts Rewrite, or USOAR, which was mandated by the FCC and implemented in 1988.

[2]Form M price change information was available for Ameritech, Bell Atlantic, Bell South, NYNEX, Pacific Telesis, Southern New England, Southwestern Bell, and U S West. This information was used to construct the price indexes for local, intrastate access, and long distance service in this study.

are then used to construct a price index. Appendix 2 of this report provides a detailed description of this methodology.

Because the interstate access rate change information filed in the Form M is not as comprehensive as the information filed by the companies for intrastate price changes, other methods are used to construct price indexes for interstate end user access, interstate switched access, and interstate special access. The price index for interstate end user access is computed as the ratio of end user access revenue to the number of access lines, where both revenue and access lines are taken from the Form M report. To compute a price index for interstate switched access, a quantity index is first computed. This quantity index is a Tornqvist[3] index of LEC common line minutes of use and traffic sensitive minutes of use, where carrier common line and traffic sensitive revenues are used as weights. Once the quantity index is computed, the price index is obtained by dividing booked revenue by the quantity index. Finally, a special access price index is developed from LEC data on prices for special access services.

For local service, interstate end user access, interstate switched access, and interstate special access, the quantity indexes are obtained by dividing booked revenue by the corresponding price index. For intrastate access and long distance service, a different approach is necessary. The reason is that the price indexes represent the prices paid by customers, while the revenue represents the revenue

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[3]The Tornqvist index determines the rate of growth of a quantity index by weighting the growth of each of the services in the index by each service's revenue share.

received by the companies. Because of the settlements process, the revenue received by the company does not equal the amount paid by the customer. Consequently, we obtain quantity indexes for these services by dividing billed revenue by the corresponding price index.[4]

Since miscellaneous services represents a wide variety of activities, the U.S. Gross Domestic Product Price Index (GDPPI) is used as the price index for this category. The quantity index for miscellaneous services is obtained by dividing adjusted booked revenue by the GDPPI.

Total Output

The quantity indexes for the revenue categories are aggregated using the Tornqvist index. The index produces an overall rate of growth in total output by weighting the growth rates for each revenue category. The weights used in the computation are the revenue shares of the categories, where the adjusted revenues described above are used in constructing the weights.

1.2 Total Input--Methods

Total input is comprised of capital (plant and equipment), labor, and materials, rents, and services (hereafter referred to as materials). To construct a quantity index of total input, quantity indexes for capital, labor, and materials are constructed. The

[4]As noted above, the price index for interstate access is constructed using booked revenues. In this case, revenue and price indexes both represent the revenue received by the companies.

capital, labor, and materials quantity indexes are then aggregated using the Tornqvist index to obtain the quantity index of total input, with cost shares serving as the weights for the various categories.

Capital

The quantity and cost of capital input is based on the Christensen-Jorgenson methodology.[5] Six asset classes are distinguished: buildings, general support equipment, central office equipment (including operator systems), transmission equipment, information origination/termination equipment, and cable and wire. The quantity of capital stock is calculated for each asset class using the perpetual inventory capital stock equation, which has the form:

$$K_t = (1 - \delta)\cdot K_{t-1} + I_t \tag{1.1}$$

where

K_t = the quantity of capital stock at the end of year t
I_t = the quantity of investment during year t
δ = the economic rate of replacement.

The economic rates of replacement used in the study are taken from Jorgenson.[6] The rates are: 15.5% for general support equipment, 11.0% for central office equipment, transmission equipment, and information origination/termination

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[5]See Christensen and Jorgenson, 1969.

[6]D.W. Jorgenson, "Productivity and Economic Growth," in E.R. Berndt and J.E. Triplett, eds., Fifty Years of Economic Measurement (Chicago: University of Chicago Press, 1990), pp. 19-118.

equipment, and 2.3% for buildings and cable and wire. The quantities of investment are obtained by dividing the value of investment by the corresponding investment price deflators, also known as Telephone Plant Indexes. The LECs provided Telephone Plant Indexes for each of the asset classes, for each year. The values of additions to plant are based on data reported in the Form M, which need to be adjusted for the USOAR accounting changes. The primary accounting change affecting the measurement of capital occurs in 1988. Starting in 1988, some expenditures that had previously been reported as additions to plant were now required to be reported as operating expense. In 1988, operating expense for the LECs increased by $2.1 billion because of these accounting changes. This figure was used as the basis for adjusting reported gross additions for the 1984-1987 period.

A starting value, or benchmark, for K must be calculated in order to apply the perpetual inventory capital stock equation. We calculate a 1984 benchmark for each asset class, based on the 1984 replacement cost as provided by the LECs. This 1984 replacement cost is a "current cost of gross plant" measure. That is, assets of different vintages are repriced to provide a common basis of valuation. It is necessary to adjust the replacement cost for the age distribution of the assets. The U.S. Bureau of Economic Analysis reports the age distribution of the relevant assets for the telecommunications industry. This industry age distribution of plant and equipment is used to derive the LEC age distribution of plant and equipment. The LEC age distribution is then used to obtain a benchmark value for each asset class. Finally, an adjustment for USOAR is also necessary for the benchmark, since the data underlying the benchmark estimate are based on the pre-USOAR accounting standards.[7]

Once the quantity indexes are computed for each of the asset classes, they must be aggregated into an overall capital input index. The weights used to aggregate the asset classes are the annual capital costs of each asset class (also referred to as the "implicit rental" costs). The annual cost of capital services for each asset class is calculated using the Christensen-Jorgenson methodology and includes four components: (1) the opportunity cost of the capital held in the form of plant and equipment; (2) plus cost of declines in efficiency of plant and equipment; (3) less the economic revaluation of plant and equipment; (4) plus the cost of property taxes and profits taxes.[8]

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[7]There is one caveat with respect to the 1984 benchmarks used in the study. The 1984 replacement cost for information origination/termination equipment includes some inside wire. Although inside wire maintenance was deregulated, the companies had not recovered the original cost of inside wire in place at the beginning of 1984. In order to recover the remaining cost of the inside wire, it was included in the rate base, and consequently in the plant and equipment reported in the Form M. Because inside wire was included in plant and equipment solely for cost recovery purposes, it is appropriate to exclude it from the TFP study. Accurate identification of the replacement cost of the inside wire was not possible. To approximate the impact of removing inside wire, we recalculated TFP growth based on the assumption that information origination/termination equipment grows at the same rate as the other plant and equipment categories. This recalculation results in annual average TFP growth of approximately 2.2 percent, yielding a TFP growth differential between the LECs and the private business sector of approximately 1.3 percent. Thus, the results reported in Table 1, which are based on not adjusting for inside wire, indicate higher TFP growth than if we had adjusted for inside wire.

[8]See Christensen and Jorgenson, 1969. The Christensen-Jorgenson formula for the implicit rental price is:

$$v_t = [(1 - u \cdot z - k)/(1-u)] \cdot [r_t \cdot p_{t-1} + \delta \cdot p_t - (p_t - p_{t-1})] + \tau \cdot p_t ,$$

For each of the asset classes, the four components of annual capital costs are calculated as follows. First, the opportunity cost of the capital held in the form of plant and equipment is calculated by multiplying the current economic value of plant and equipment by the appropriate interest rate. The current economic value of plant and equipment is obtained by multiplying the quantity of the capital stock by the relevant Telephone Plant Index. The interest rate used as the opportunity cost is Moody's Composite Yield on Public Utility Bonds. Second, the cost of declines in efficiency is obtained by multiplying the economic rates of efficiency decline by the current economic value of plant and equipment. Third, the economic revaluation of plant and equipment is obtained by multiplying the quantity of capital stock by the change in the relevant Telephone Plant Index. Fourth, the cost of property and profits taxes is based on taxes reported in the Form M.

Once the quantity indexes and costs are calculated for each of the asset classes, the quantity index of total capital input is computed as a Tornqvist index of the asset classes, with their capital service costs as weights. The total cost of capital input is equal to the sum of the costs for the six asset classes.

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where u is the rate of taxation on income, z is the present value of tax depreciation allowances, k is the investment tax credit rate, r is the interest rate (Moody's yield on public utility bonds), p is the Telephone Plant Index, δ is the rate of economic replacement (representing the declines in efficiency), and τ is the rate of property taxation. The income tax rate, the property tax rate, and the investment tax credit rate are based on income taxes, property taxes, and investment tax credits reported by the LECs in the Form M report. The present values of tax depreciation allowances are based on the tax lifetimes and depreciation formulas specified by law.

Labor

Labor input includes the time spent by LEC employees in providing services to LEC customers. It does not include the time installing plant and equipment, since this input is included in the capital input measure. Two groups of employees are distinguished in the TFP study: management and non-management.

The cost of labor input is equal to expensed wages and salaries plus expensed benefits. The total cost of labor is reported in the Form M report. The LECs provided us with a breakdown of labor costs into management and non-management labor costs. The LECs also provided to us total management hours worked and non-management hours worked. The quantity index of labor input is a Tornqvist index of management and non-management hours worked, with management and non-management labor costs used as weights.

Materials, Rents, and Services (Materials)

The cost of materials is equal to total operating expense less depreciation and payments to labor. This information is reported in the Form M. Since the materials data are based on data filed in the Form M, adjustments must be made for the USOAR accounting changes. The two major changes affecting materials are the treatment of nonregulated activities (discussed in our previous section on output) and the shifting of expenditures from the plant and equipment account to the operating expense account (discussed in our previous section on capital input). The LECs provided us the necessary adjustment figures. The Gross Domestic Product Price Index is used to represent the price of materials, since this category is comprised of a diverse set of inputs. The quantity index of materials is obtained by dividing materials cost by its price.

1.3 Total Output, Total Input, and Total Factor Productivity--Results

The index of TFP is computed as the ratio of the quantity index of total output to the quantity index of total input. Equivalently, the rate of growth of TFP is computed as the rate of growth of the quantity index of total output minus the rate of growth of the quantity index of total input.

Table 1 shows the quantity index of total output, the quantity index of total input, and the TFP index. Also shown are the annual rates of growth in total output, total input, and TFP. Over the 1984-1992 period, total output grew at an average annual rate of 3.5 percent,[9] total input grew at an average annual rate of 0.9 percent, and TFP grew at an average annual rate of 2.6 percent.[10]

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[9]All percent growth rates that we report are computed using natural logarithms. For example, for the average annual growth of output between 1984-1992, 3.5% = ((ln 1.322 - ln 1.000)/8) x 100.

[10]A sensitivity analysis was performed to assess the impact on the TFP results of our adjustments for the accounting changes regarding non-regulated revenues and expenses, and the shifting of expenditures from capital to expense accounts. Failure to adjust for non-regulated revenues and expenses has no material impact on the results. Failure to adjust for the capital to expense shift would lower average annual TFP growth over the study period to 2.3 percent. Based on an average annual rate of growth for the private sector of 0.9 percent, the failure to adjust for the capital to expense shift lowers the TFP growth differential between the LECs and the private business sector to 1.4 percent.

Table 1

Local Exchange Carrier Total Factor Productivity

	Total Output Index	Total Output Growth Rate	Total Input Index	Total Input Growth Rate	TFP Index	TFP Growth Rate
1984	1.000		1.000		1.000	
1985	1.031	3.0%	1.012	1.2%	1.019	1.9%
1986	1.062	3.0%	1.015	0.3%	1.047	2.7%
1987	1.103	3.8%	1.033	1.8%	1.068	2.0%
1988	1.160	5.0%	1.065	3.0%	1.089	1.9%
1989	1.219	5.0%	1.094	2.7%	1.114	2.3%
1990	1.266	3.8%	1.086	-0.7%	1.165	4.5%
1991	1.295	2.3%	1.099	1.2%	1.178	1.1%
1992	1.322	2.1%	1.078	-1.9%	1.227	4.0%
Average Growth 1984-92		3.5%		0.9%		2.6%